



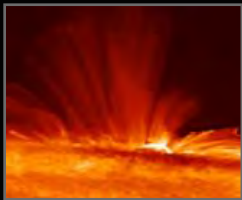
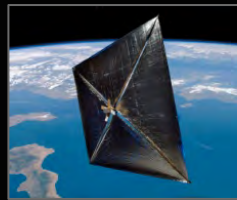
Marshall Space Flight Center

Science and Technology Overview and Additive Manufacturing Special Topics

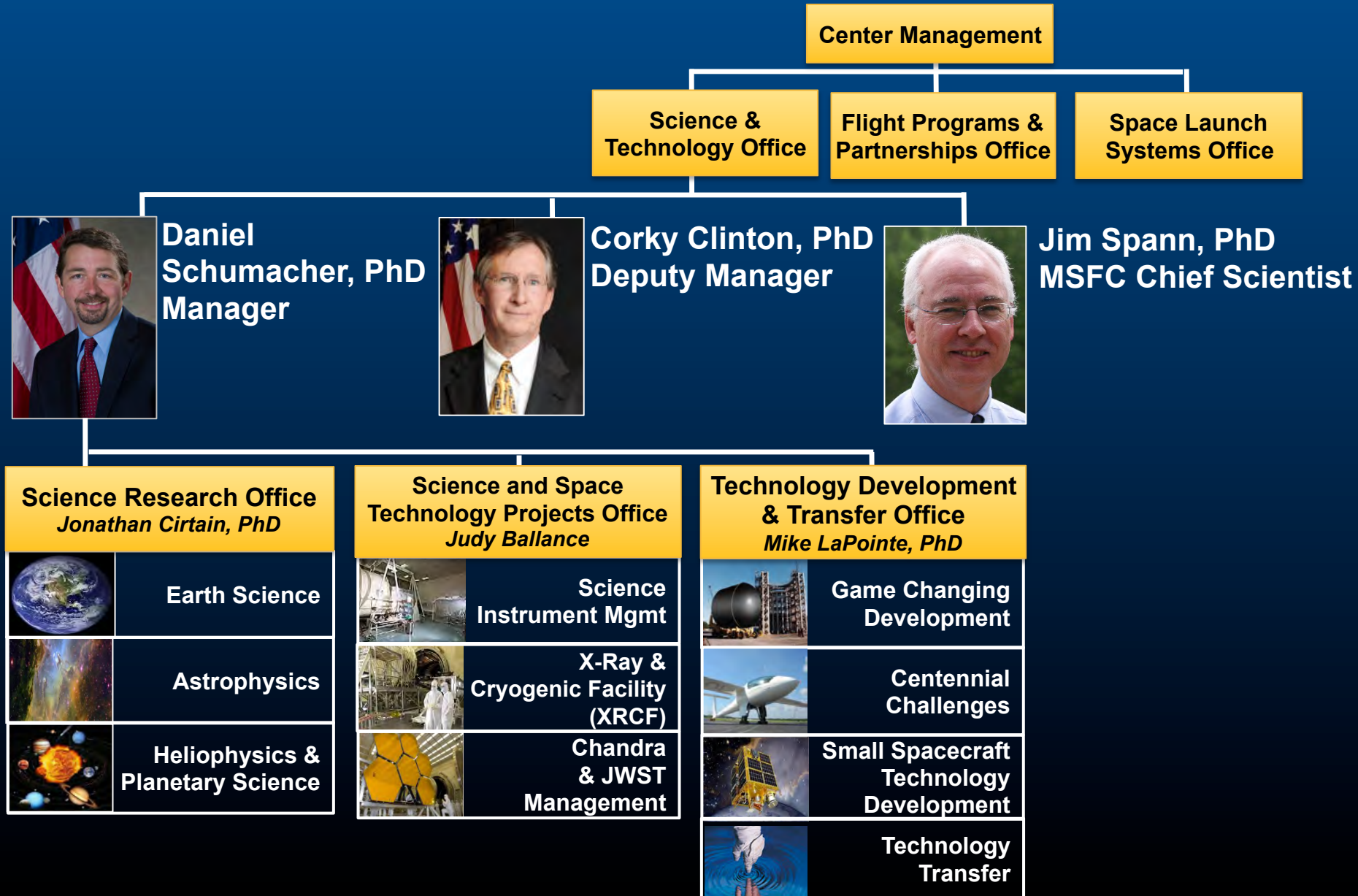
Huntsville Aerospace Marketing Association

March 11, 2016

marshall



Organizational Structure



Organizational Factoids



**HAS OVER 55
PROGRAMS/ PROJECTS
IN ITS PORTFOLIO**

**INCLUDES 200
TEAM MEMBERS;
~110CS + ~90WYE**

**PROJECTS
RANGE FROM <
\$100K TO \$1B**

**PROJECTS RANGE
FROM PRE-PHASE A
TO PHASE E**

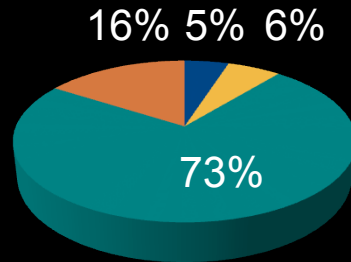
**Science
& Technology
Factoids**

**INCLUDES WORK
FROM THREE OF
NASA'S FOUR
MISSION
DIRECTORATES**

**40% OF NASA-
EMPLOYED
SCIENTISTS AND
TECHNOLOGISTS
HOLD DOCTORATE
DEGREES**

FY15 Business Data

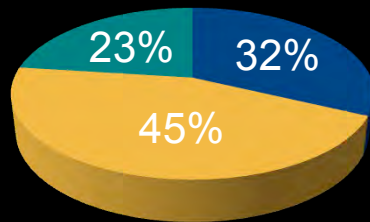
Office Budget



- Reimbursables
- Exploration Systems
- Science
- Technology

Much of our budget comes from NASA's Science Mission Directorate (SMD) and Space Technology Mission Directorate (STMD)

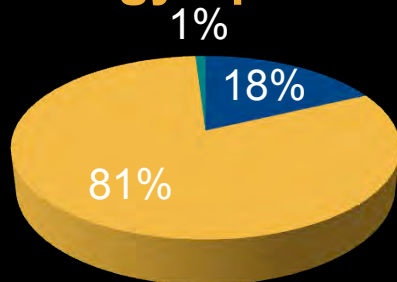
Science and Technology Funding



- Science Directed
- Science Competed
- Technology Directed

Much of our Science budget is competed, while all of our technology work is directed.

Science and Technology Spending



- Labor
- Procurement
- Travel

A large part of our science and technology budget is spent on procurement.

Science



Chandra X-Ray Observatory



Chandra Spots Oldest Light in the Universe 1.22.16



Advanced X-Ray Optics

X-ray and Cryogenic Testing



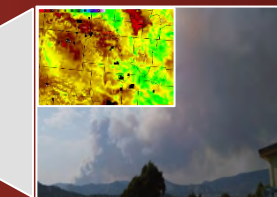
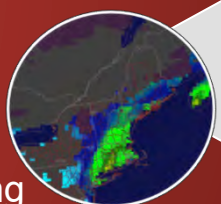
Fermi Gamma-ray Burst Monitor



Hurricane Imaging Radiometer



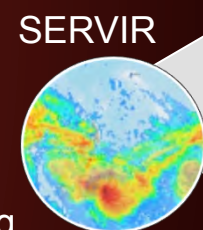
SPoRT



New Mexico Wildfires and Soil Moisture Data 8.21.15



Lightning Imaging Sensor (ISS)

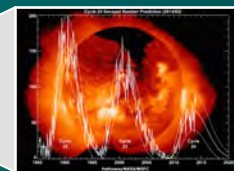


SERVIR Airds in Neapl Quake 5.4.15

SERVIR



Space Weather Research



SWEAP

Sounding Rocket Investigations



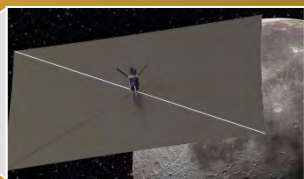
HINODE



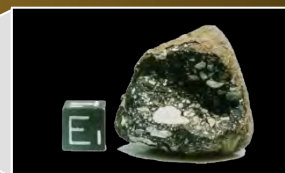
Hinode Images Present a New Explanation of How Solar X-ray Jets Occur 8.31.15



PI for NASA Lunar Flashlight



Finding Lunar Volatiles Using CubeSats

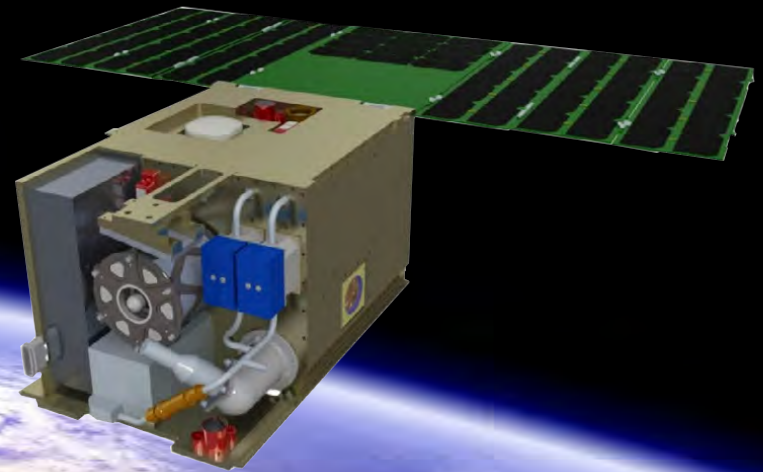


Providing the Formation Age of Rocks and Meteorites

MSFC Noble Gas Research Laboratory



Providing the ability to alter orbit inclination and elevation, and control deorbit for cubesats.

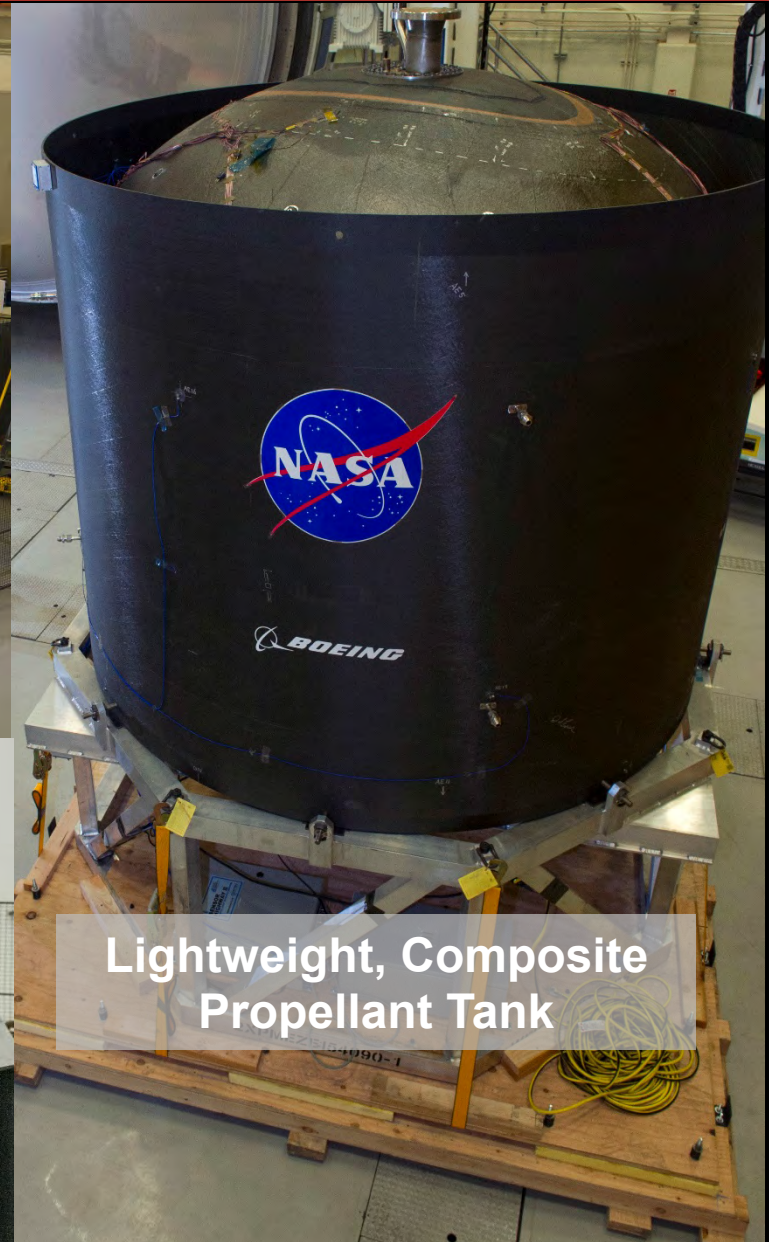
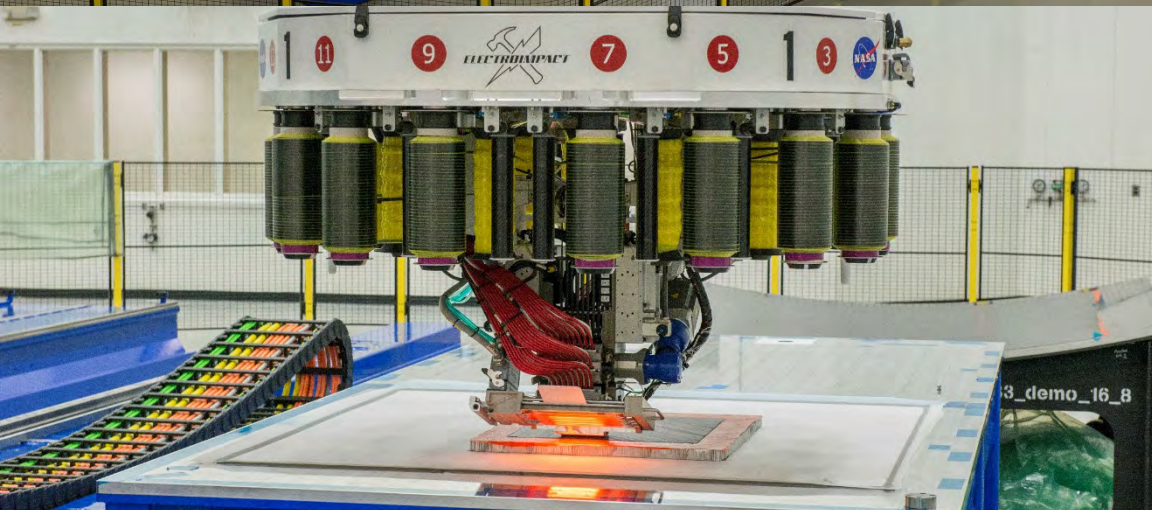


Nuclear Fuels Testing



Nuclear thermal propulsion offers twice the specific impulse as traditional chemical engines and reduces trip time to Mars.

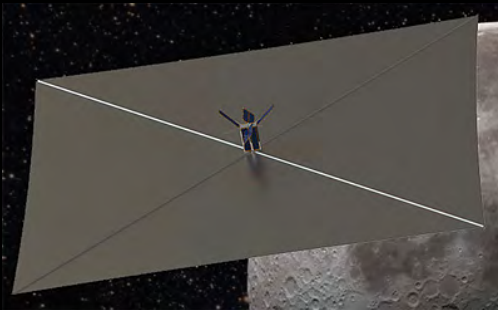
Composite Technology Demonstrations



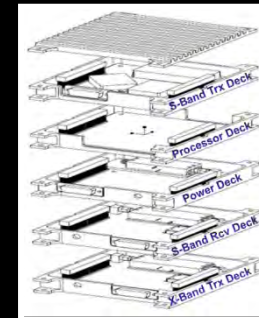


FASTSAT (2010-2012)

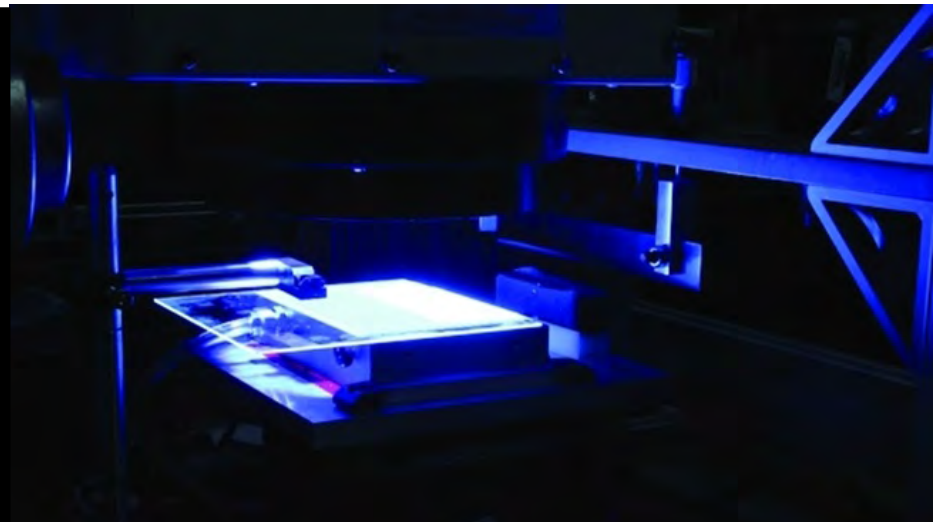
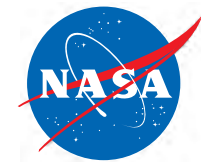
**MSFC/Dynetics partnership
built and launched
FASTSAT, a microsatellite,
from which Nanosail-D, a 3U
cubesat was launched.**



**Near-Earth Asteroid Scout, 6u
Cubesat**



**PULSAR
Programmable Ultra Lightweight
System Adaptable Radio**



Additive Manufacturing Special Topic

Marshall Space Flight Center

Additive Manufacturing Path to Exploration



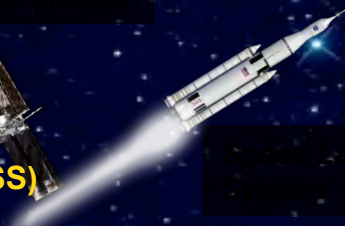
EARTH RELIANT

Earth-Based Platform

- Certification & Inspection Process
- Design Properties Database
- Additive Manufacturing Automation
- In-space Recycling Technology Development
- External In-space Manufacturing and Repair
- **AM Rocket Engine Development, Test, and Certification**
- **AM for Support Systems (e.g., ECLSS) Design, Development, Test**



International Space Station



Space Launch System



Commercial Cargo and Crew

PROVING GROUND

Space-Based Platform

- 3D Print Tech Demo
- Additive Manufacturing Facility
- On-demand Parts Catalogue
- Recycling Demo
- Printable Electronics Demo
- In-space Metals Demo
- **AM Propulsion Systems**
 - RS-25
 - Upper Stage Engine
- **Habitat Systems**

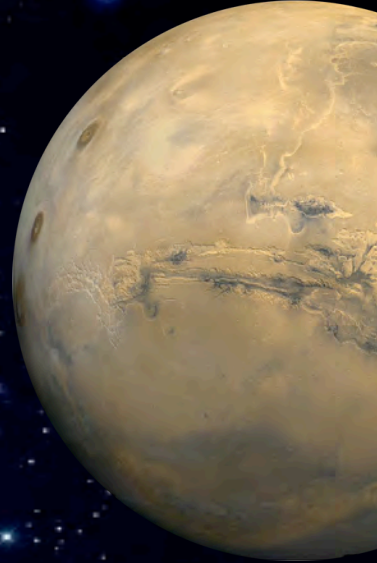


Asteroid

EARTH INDEPENDENT

Planetary Surfaces Platform

- Additive Construction Technologies
- Regolith Materials - Feedstock
- **AM In Space Propulsion Systems**
 - Upper Stage
 - Orbiters
 - Landers
- **Habitat Systems**

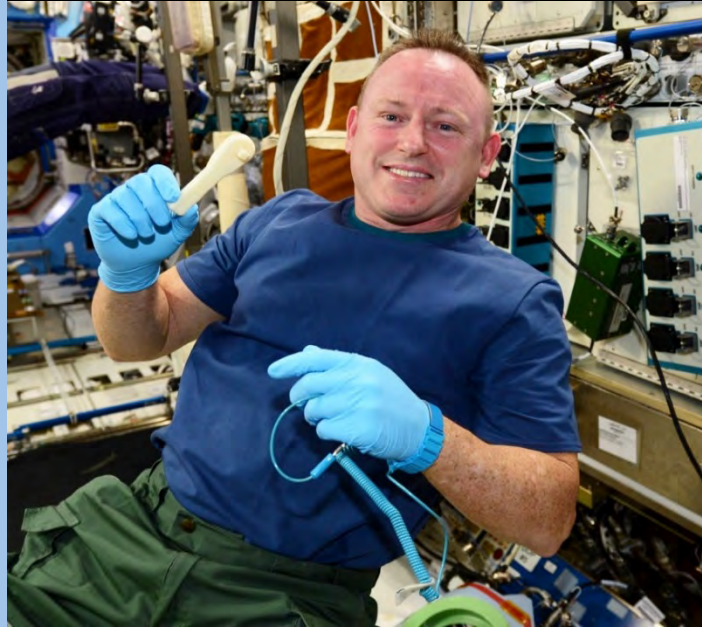
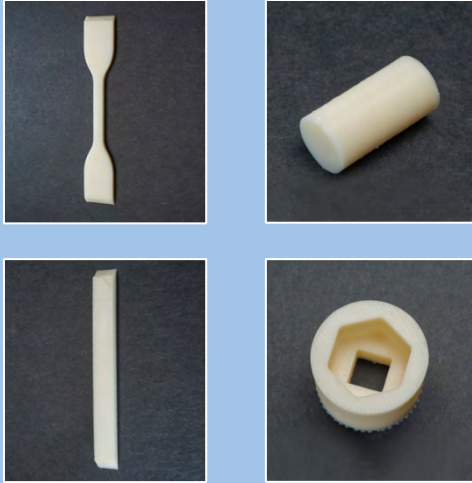


3D Printer International Space Station (ISS)

Technology Demonstration - Preliminary Results



Mechanical Property Test Articles



Functional Tools



- A total of 21 parts were printed on ISS, including the uplinked ratchet handle.
- Inspection and testing of all articles included:
 - Structured light scanning
 - X-ray and CT scan
 - Microscopy
 - Density
 - Mechanical testing
- Mechanical property differences observed between flight and ground samples
- Additional ISS prints in Spring 2016 will enable additional mechanical properties data and support hypotheses evaluation
- Lessons Learned have been incorporated into the next generation 3D Printer for ISS – Additive Manufacturing Facility (AMF) by Made In Space

Collaborative Additive Construction Projects



Additive Construction with Mobile Emplacement (ACME)



Shared Vision: Capability to print custom-designed expeditionary structures on-demand, in the field, using locally available materials.

Automated Construction of Expeditionary Structures (ACES)



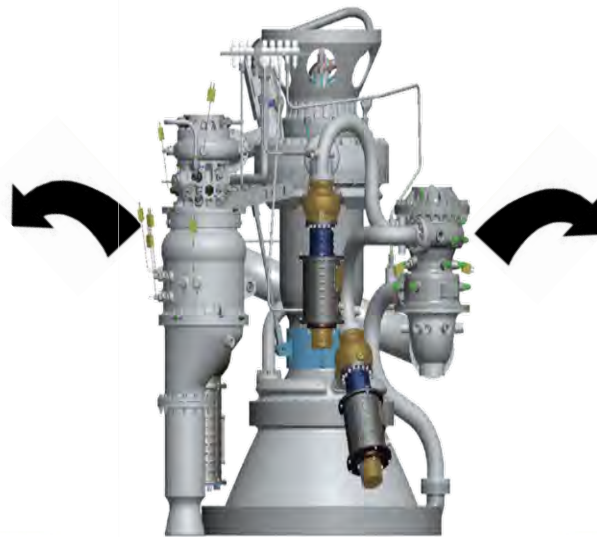
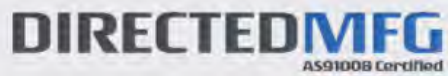
Strategic Vision for Future AM Engine Systems



Defining the Development Philosophy of the Future

- Integrating Design with Manufacturing
- 3D Design Models and Simulations Increase Producibility
- Transforming Manual to Automated Manufacturing
- Dramatic Reduction in Design Development, Test and Evaluation (DDT&E) Cycles

Building Foundational Industrial Base



Bridging the gap
between the present
and future projects that
are coming



**Transferring "Open Rights"
SLM Material Property Data
& Technology to U.S.
Industry**

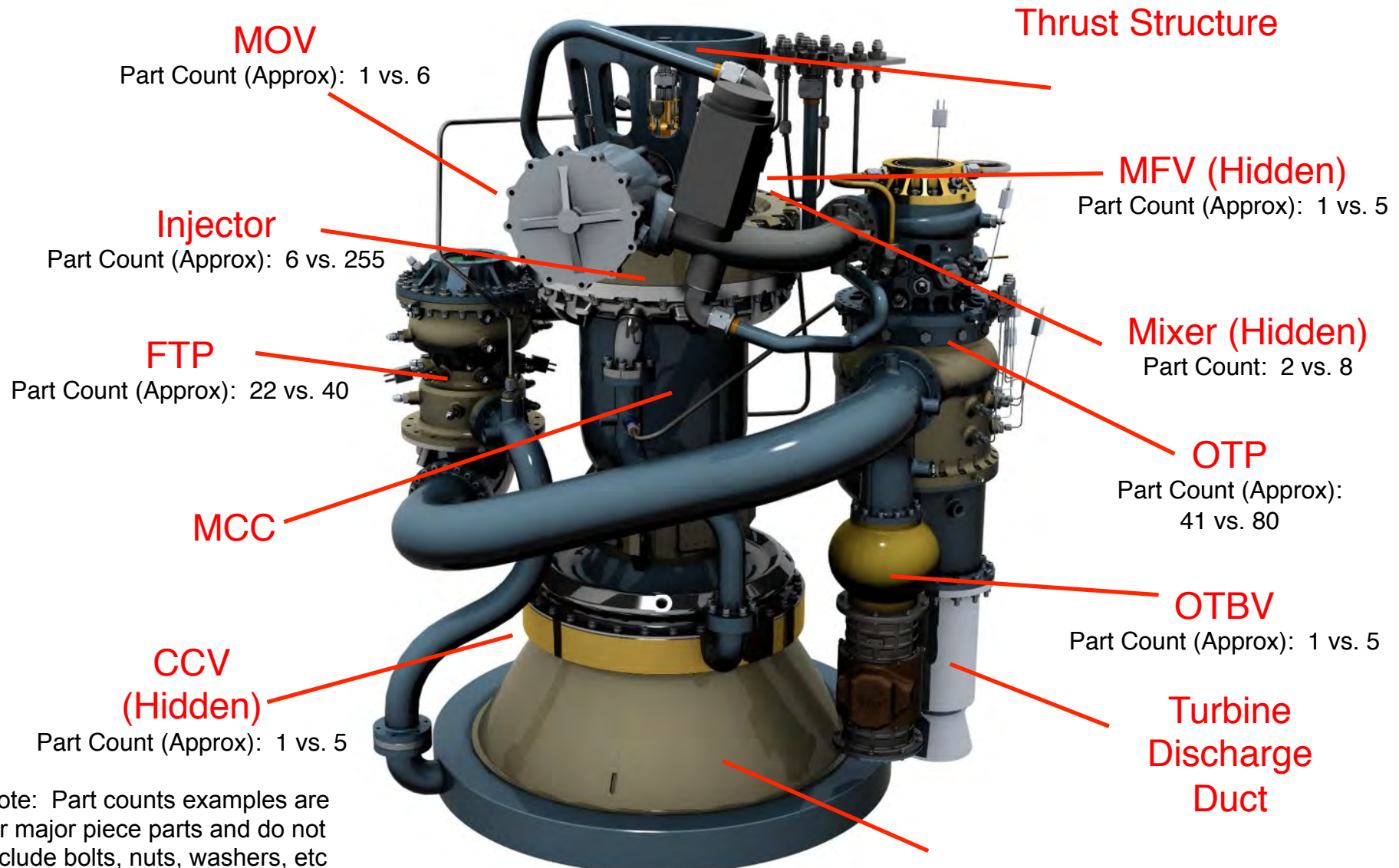
Building Experience "Smart Buyer" to enable Commercial Partners



Enabling & Developing Revolutionary Technology

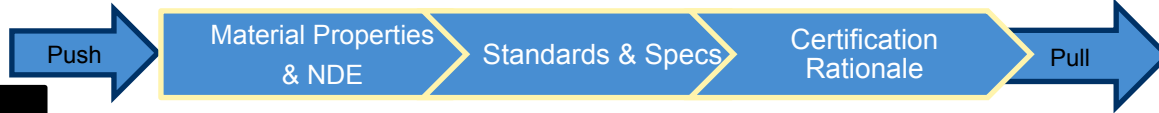


Reduction in Parts Count for Major Hardware

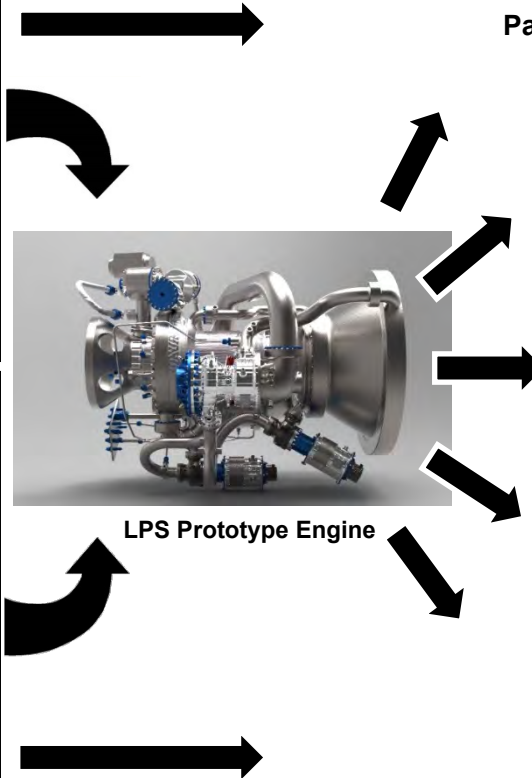
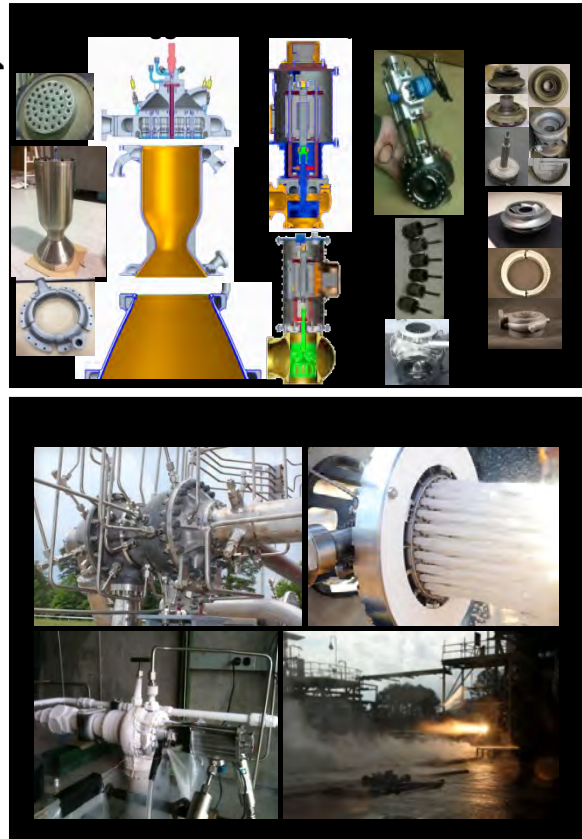


Reduction in Parts Count for Major Hardware

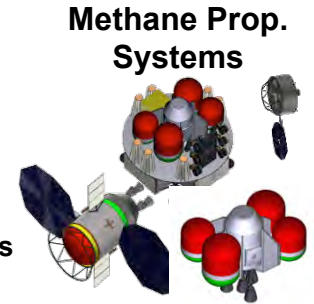
Fundamental Additive Manufacturing M&P Development



Parallel & Congruent Activities



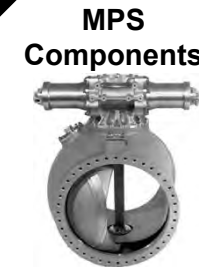
Payloads & Satellites
RP Engine



Methane Prop. Systems



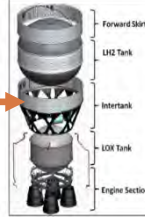
Nuclear Propulsion



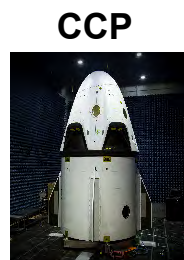
MPS Components



Upper Stage Engine



RS-25



CCP

Building Foundational Additive Manufacturing Industrial Base

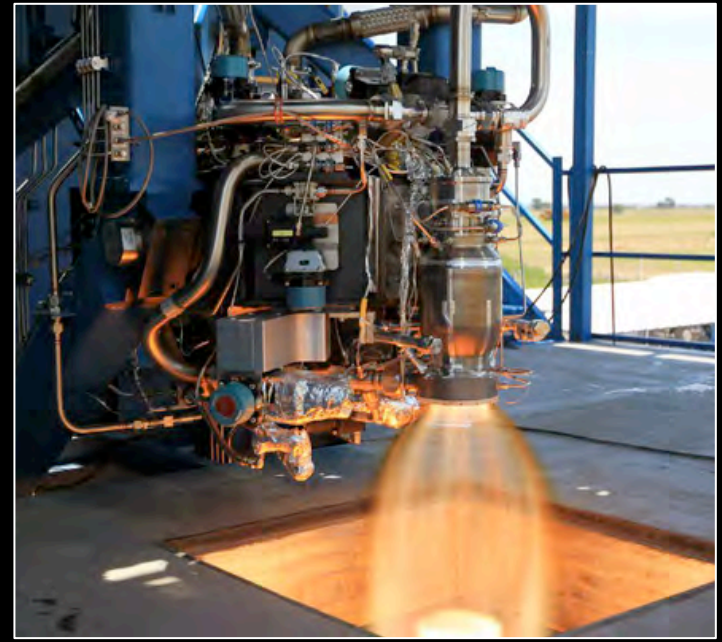


AM in the Human Exploration and Operations Portfolio

Exploration Systems Development ORION and SLS



Commercial Crew Program DRAGON V2



**Requirement choices dictate how we embrace, foster,
and protect the technology and its opportunities**

Engineering and Quality Standard for AM Spaceflight Hardware



National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

MSFC-STD-xxxx
REVISION: DRAFT 1
EFFECTIVE DATE: Not Released

EM20

MSFC TECHNICAL STANDARD

Engineering and Quality Standard for Additively Manufactured Spaceflight Hardware

DRAFT 1 – JULY 7, 2015

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DO NOT USE PRIOR TO APPROVAL

CHECK THE MASTER LIST—
VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

THIS STANDARD HAS NOT BEEN REVIEWED FOR EXPORT CONTROL RESTRICTIONS
DRAFT VERSIONS DISTRIBUTED FOR REVIEW ARE NOT TO BE DISSEMINATED

- ***Tailoring***
- Governing standards
- AM Design
- ***Part Classification***
- Structural Assessment
- Fracture Control
- Qualification Testing
- Part Development Plans
- ***Process Controls***
- ***Material Properties***
- Finishing, Cleaning, Repair Allowances
- Part Inspection and Acceptance

Technology Transfer

Bringing NASA Technology Down to Earth

Free Software Release

Patent Licensing

Spinoffs



NASA 398 Alloy Used in All
Evinrude E-TEC Engines

Marshall Space Flight Center
Technology Transfer Office



Specific Opportunities

2016 Dual Use Technology Development Cooperative Agreement Notice (CAN) at NASA MSFC

- **NNM16567212C**
- **Released October 9, 2015; Response Date:**
- **Scope: Award cooperative agreements for technology development partnerships. MSFC resource contribution awards range from \$10,000 to \$100,000.**
- **The next opportunity deadline to submit a White Paper is 4 May 2016.**
- **FYI: Any Cooperative Agreement projects selected for this 4 May opportunity will most likely start sometime in Oct and use FY17 funds for the MSFC contribution.**

Commercial Space Technology Development RFI

- **NNH16ZOA001L**
- **Released January 14, 2016; Response Date: February 25, 2016**
- **Scope: Seeking input to inform topic areas for future STMD Tipping Point and Announcement of Collaborative Opportunity solicitations.**



www.nasa.gov/marshall